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FRIENDSHIP INTERNATIONAL AIRPORT

By Benjamin Everett Beavin, Sr., M. ASCE

AIR TRANSPORT DIVISION

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AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS

FRIENDSHIP INTERNATIONAL AIRPORT

By Benjamin Everett Beavin,[1] Sr., M. ASCE

Synopsis

The design of Friendship International Airport at Baltimore, Md., embodied many advances in the theory of airfield layout. The airport was considered to consist of two parts, the airfield and the terminal, and each of these parts was designed to function with a maximum of convenience and efficiency.

The factors affecting design and construction of the airfield are outlined and discussed, and a brief description of the construction phase is given.

The design factors influencing the layout and orientation of the terminal are presented, along with their effect on normal operations. Passenger handling is described, and the service facilities in the terminal are outlined in their relation to the traveler and the airline operation and maintenance.

Introduction

Friendship International Airport was designed and constructed in a period of 5 years between 1945 and 1950. The first 2 years were devoted largely to research covering many air, bus, railroad, and marine terminals, surveys, conferences with aviation officials, airlines, travelers and prospective concessionaires, and planning and preparation of the master plan. This paper has been prepared for the purpose of making available to the profession any knowledge that may have been gained during this 5-year period.

In order to simplify the problem, the design of an airport may be considered to consist of 2 parts: (1) The part most intimately connected with flight, such as the air above and around the airport, approach and landing facilities, runways, taxiways, and aprons that for convenience are called the airfield; and (2) the access road, interior roads, fuel storage, auto parking areas, hangers, shops, industrial areas, and last but not least, the terminal building. This second part, mainly devoted to earthbound activities, is called the terminal.

The division of the airport into 2 major parts leads to the realization that the length of the boundary line between the two is one important index of the facil-

Note.—Written comments are invited for publication; the last discussion should be submitted by April 1, 1952.

[1] Cons. Eng., Linthicum Hts., Baltimore, Md.

ities provided. This boundary line may be defined as the apron frontage line. The total cost of Friendship International Airport, including land, legal, engineering, utilities, and administrative expense, and all construction contracts was approximately $15,000,000. Dividing the total cost by the 3,100 linear ft of apron frontage presently constructed (1950) indicates a cost of approximately $5,000 per front ft. Friendship Airport has a potential apron frontage of 7,700 linear ft. A great deal of apron area has been graded but not paved; therefore, it is not included as completed apron frontage.

Obviously, this apron frontage is far too valuable to be dedicated permanently to any activity that does not contribute heavily to aviation. All airport design should be carried out with this thought in mind.

Airfield Design and Construction

Design Factors.—Having established two parts of an airport, it is logical to consider first the design of the airfield.

There are many criteria for airfield design, but the most important are: (*a*) Safety; (*b*) economy of construction; (*c*) economy of airline operation; and (*d*) economy of maintenance.

(*a*) *Safety.*—Many factors contribute to a safe design. Among others it is important to consider uncrowded airways, unobstructed approaches, adequate navigation aids, zoning protection, wide and long runways, ample taxiways, and freedom from fog and wind vagaries.

(*b*) *Economy of Construction.*—By careful site selection, avoidance of unnecessary approach-zone damage to near-by property, exploitation of on-site and near-site materials, careful subsurface surveys, and preparation of specifications that take as many risks from the contractor as possible, it is feasible to secure the maximum utilization of the available funds. Under the best of conditions, the contractor is still subject to plenty of risks, and bid prices are bound to reflect them.

(*c*) *Economy of Airline Operation.*—Many factors affect this phase of design, including expeditious landings, favorable meteorological conditions, short taxiway distance, ample apron facilities for quick turn-around, and lack of restrictions on take-off weights. An approximate measure of the direct cost per ton-mile of airborne persons or cargo may be obtained by dividing the airplane cost of operation per hour by the product of velocity between terminals and the pay load. Restrictions due to airfield deficiencies affect not only the landing and take-off at the airport but may limit the load for the entire trip, thereby increasing the cost per ton-mile. Friendship Airport is fortunate in having no such weight limitations.

(*d*) *Economy of Maintenance.*—Careful drainage design, adequate sub-base construction, wind and water erosion control, and pavements designed for resistance to heavy loads, weather, and scuffing will reduce maintenance costs.

Details of Site.—With these general criteria well in mind, the Baltimore City Department of Aviation selected a 3,200-acre site for Friendship International Airport 9 miles southwest of the center of the city, alongside the Baltimore-Washington Expressway, which is now partially completed. The

airport abuts the Pennsylvania Railroad and is not far from the Baltimore and Ohio Railroad. Its surface transportation facilities, when completed, will be ideal. It is located on a plateau some 140 ft above sea level. The soil is sandy, drainage is away from the airfield in all directions, and the site is remarkably free from fog and smoke.

Design and Construction.—The details have been rather thoroughly documented[2,3] but the important highlights of the airfield design and construction will be presented as background for the terminal design. Economy of construction demands that all materials on a given site be utilized insofar as possible in the construction of the airfield. Few sites are blessed with abundant supplies of sub-base or pavement material deposited in such large quantities that they may be economically salvaged and used. More often, deposits are found scattered throughout the area with a greater or lesser amount of overburden. The latter was the case at Friendship Airport. Many small deposits of sand gravel, suitable as aggregate for sand-gravel asphalt, were encountered as the grading operation proceeded.[4,5] Materials from these deposits were routed to stock piles located near the future site of the asphaltic concrete hot mix plants.[6]

Culverts under the older highways were seldom long enough to cause dangerous acceleration of the water flowing through. This is not the case, however, with culverts under modern dual highways or under airport runways and taxiways. In the long culverts at Friendship, velocities were found to increase from 5 ft per sec at entrance to 15 to 25 ft per sec at exit. With soils that erode at velocities of about 5 to 6 ft per sec, these high exit velocities could not be tolerated. The solution adopted was to flatten the lower end of the culverts so as to cause the hydraulic jump to occur within the structure, thus reducing the exit velocities to a safe figure.

Where fills over culverts were comparatively low, concrete cradles were necessary to enable the culverts to withstand the heavy loads from the expected use of the 200-ton pneumatic roller[7,8] and the 150,000-lb wheel load for which the airfield is designed. Concrete made of imported aggregates would have cost $30.00 per cu yd in place. By mixing 3 bags of cement with a cubic yard of sand-gravel aggregate taken from trench side, the cost was reduced to $8.00 per cu yd. Tests indicated a crushing strength of approximately 900 lb per sq in., which was considered adequate for cradle construction.

The light sandy soil at the site was very susceptible to wind and water erosion. Therefore, soil erosion control measures were made a part of the very first and all succeeding grading contracts. Weather permitting, as soon as an area was finally graded, it was fertilized, seeded, and mulched. In

[2] "Master Plan Report, Friendship International Airport," submitted to Baltimore City Aviation Commission, June 24, 1946, by Whitman, Requardt-Greiner Company and Associates.

[3] "Baltimore Breaks Airport Precedent," *The American City*, Vol. 63, November, 1948, p. 101.

[4] "50,000 cu. yd. Daily for Baltimore Airport," *Engineering News-Record*, Vol. 139, 1947, p. 532.

[5] "Baltimore Airport Grading . . . Three Types of Rigs for Various Hauls." *Construction Methods*, Vol. 30, January, 1948, p. 102.

[6] "Asphaltic Surfacing Details at Baltimore Airport," by B. E. Beavin, *Roads and Streets*, Vol. 92, April, 1949, p. 58.

[7] "Super Compactor Cuts Airport Construction Costs," *Civil Engineering*, Vol. 18, 1948, p. 140.

[8] "Soil Compaction at Friendship International Airport," by B. Everett Beavin, *The Military Engineer*, Vol. 40–41, July-August, 1949, p. 264.

this way, a healthy stand of grass usually was obtained before any gulleying had started. There was not sufficient topsoil on the site to build a high-grade turf over the entire disturbed area; therefore, topsoil was applied to those areas immediately adjoining runways, taxiways, and aprons, where the blasts from airplane propellers might be felt and where planes might occasionally run off the pavement. In other areas the mineral sand was fertilized, limed, and planted in rye and vetch. The following spring the rye and vetch was "disced" in and the areas replanted with grass. The resulting humus helped to keep the ground moisture within reach of the grass roots, and the stand attained has been nearly as good as that found in the topsoiled areas. In steeper and more remote areas, at the suggestion of the Soil Conservation Service (SCS), a new type grass (the African Weeping Love Grass) was planted directly upon the bare clay and sandy surfaces with very gratifying success. The seeds of this grass are so small that only 2 to 3 lb are required per acre. Being an annual it has the disadvantage that it may only be planted in the spring and early summer if it is expected to survive permanently. A total of approximately 1.5 sq miles of land was successfully tied down with vegetation so as to resist wind and water erosion.

The utilities serving the airfield are mostly conventional in their design and construction. However, even at the time of construction of Friendship Airport it seemed probable that aircraft would not always be dependent upon wind direction in landing and taking off and that in the future some of the runways might become superfluous. The matter was discussed with the Civil Aeronautics Authority (CAA) and it was decided that the city's proper course would be to proceed with the construction of three runways and to make all possible provision for future conversion of 1 or more of the runway areas into sites for industrial or other activity closely related to aviation. The power, communications, and water distribution systems were designed with this thought in mind, and at every intersection of runways and taxiways there were installed spare ducts for high and low tension wires and capped-off sections of water main. After supercompaction and before the ends were backfilled, mandrels were run through the duct lines and a pressure test was applied to the water main sections to make sure that no defects existed. These precautions will be of considerable assistance in adapting the design of the airport to accommodate the rapidly changing needs of aviation.

Sufficient aggregate was accumulated from grading operations at the site to provide 800,000 sq yd of sand gravel asphalt, 7-in. thick. The top 3 in. of pavement were composed of imported sand and crushed stone having an abrasion loss of less than 40 based on the Los Angeles abrasion test (American Society for Testing Materials Designation: C131–47). Stabilities of 1,400 were obtained, as measured with Marshall Stability Apparatus,[9,10] enabling the pavements to withstand rutting from tire pressures of approximately 250 lb per sq in. Although damage from jet fuel spillage is no longer a very serious problem, the present tendency in aircraft design is to turn jet exhausts

[9] "Formulas and Procedures for Design and Control of Asphalt Paving Mixtures," Corps of Engineers, Waterways Experiment Station, Vicksburg, Miss., June, 1948.

[10] "Investigations of Design and Control of Asphalt Paving Mixtures," *Technical Memorandum No. 3–254*, Corps of Engineers, Waterways Experiment Station, Vicksburg, Miss.

downward. This will increase the damage to paving of all kinds. The cost of the pavement was $3.00 per sq yd (1949) and would have been considerably higher if all the materials for the entire 10 in. of asphaltic concrete had been imported.

The most perfectly designed and constructed airfield will not endure very long unless its approaches are clear and protected from the encroachment of man-made hazards. Friendship Airport is protected by zoning regulations[11]

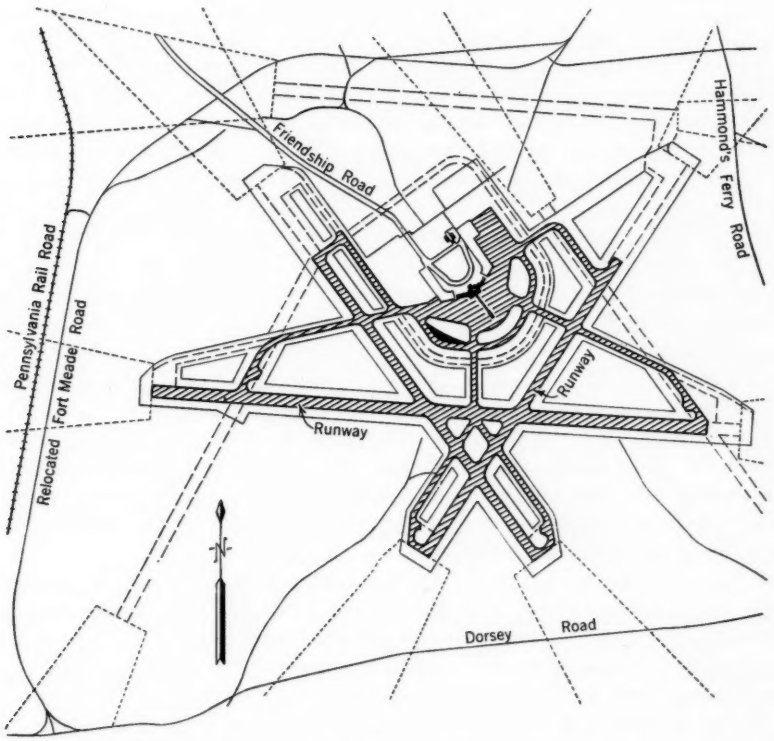

FIG. 1.—LAYOUT OF FRIENDSHIP INTERNATIONAL AIRPORT, BALTIMORE, MARYLAND

that will maintain forever the 50:1 approach glide angles, a turning zone of 8-miles diameter, and 150-ft clearance above average elevation of the field. The layout of the airfield is shown in Fig. 1.

TERMINAL DESIGN

Design Factors.—The question of terminal design involves far more complex factors than the airfield. On the airfield, the needs of aircraft are paramount and all other interests must take second place. In the case of the terminal, however, needs of many varied and often conflicting interests come into focus

[11] "Zoning Protection for Friendship International Airport," by B. E. Beavin, *The Military Engineer*, Vol. XLII, January-February, 1950, p. 35.

and must be given the consideration that each deserves. The more important of these interests are:

1. Passengers and the general public;
2. The taxpayer as represented by the airport management;
3. The airline ticketing, operating, and repair facilities; and
4. Related activities such as the CAA, Weather Bureau, Customs, Health, and Immigration.

1. *Passengers and the General Public.*—Those who use airports expect and are entitled to swift, safe access roads, ample parking space, pleasing grounds, a commodious, comfortable building that will accommodate surges in traffic, a simple, easily understood circulation scheme, efficient ticket and baggage handling, comfortable lounge and rest rooms, and concessions and conveniences such as are found in railroad terminals. Also required are complete separation of passenger facilities from baggage and freight handling and aircraft servicing activities. The shortest and simplest walking route should be provided from lobby to plane side, protected insofar as possible from the weather. The general public also has a right to expect that the terminal will provide facilities to handle air mail, air freight, and air express, swiftly and economically. Obviously, if a terminal satisfies these conditions, it will do a great deal toward increasing interest in aviation in the community in which it is constructed.

2. *The Taxpayer, as Represented by the Airport Management.*—It is expected by the taxpayer that the terminal will be designed so as to utilize the apron frontage to the maximum advantage. Economical construction, ease of maintenance, and the inclusion of all practicable revenue producing concessions should result in the possibility of the terminal becoming a self-liquidating enterprise at an early stage of its life.

3. *Airline Operations.*—Airlines ticketing operations should be convenient to the public lobby, and should permit the possibility of future consolidated ticketing operations, although at the present time the airlines are unwilling to accept this obviously economical system as being workable. Some partial consolidations are in effect at Friendship Airport. Airlines operation offices should be conveniently situated in regard to the apron and the ticketing facilities. Hangars and repair shops should be located to make the most efficient use of the apron frontage allotted them. For many years to come, air cargo will be used as supplementary loading of aircraft that are not fully loaded with passengers. The day is not yet in sight when entirely separate passenger and freight terminals will be justified in the average city. Therefore, convenient and integral cargo handling facilities must be provided.

4. *Related Activities.*—The needs of related governmental activities are fairly well established and usually may be met satisfactorily without serious conflict with the needs of passengers, airlines, and taxpayers.

It would be interesting to chart the dozens of design criteria stemming from the various interested groups and to show the manner in which they overlap and sometimes conflict. However, such a discussion is far beyond the scope of this paper which will be limited to describing some of the more im-

portant criteria and then a description of the actual operation at Friendship International Airport.

A single plane loading position utilizes 158 ft of apron frontage. Except in the case of a small airport, the only way in which passenger walking distance may be kept within a reasonable limit, and the maximum amount of apron frontage be obtained from any given layout, is to load and unload planes on both sides of piers or fingers extending out from the terminal into the apron area. The piers increase the capacity of the terminal and conserve apron frontage in exactly the same manner as piers increase the capacity of a harbor. In this type of layout, the use factor of the loading positions is increased by not assigning loading positions permanently to any one airline but rather to require that incoming planes use the open position nearest to the main lobby.

The only practicable way to separate passengers from the service activities is to have these two interests occupy different levels of the terminal. This may not be necessary in the case of small to medium-sized airports, but there seems to be no doubt that for the larger airports vertical separation is the answer.

In the old style horseshoe-shaped terminals (in reality a string of small terminals) 32 plane-loading positions would occupy 1 mile of apron frontage. In addition to squandering the precious commodity of apron frontage, this type of layout also made it impossible to derive any substantial amount of nonaviation revenue because only a very small percentage of the total number of passengers ever had occasion to pass through the administration building. With such a low revenue potential, it is practically impossible to provide concessions and conveniences comparable to the luxurious travel facilities furnished by the airlines. Therefore, it is highly desirable that 100% of all passengers and visitors to the airport pass through the main lobby and the concession area.

Economy of operation can be aided materially by careful design. Buildings should be arranged so that most of the cleaning and other maintenance functions may be done with labor saving machinery. Heating plant, electrical shops, garages, fire department, and police headquarters should be located adjoining each other in order that fire and emergency duties may be shared by all. Boilers should be studied to determine the effect of size upon the type of licensed employee required for operation. The installation of one small steam engine may result in the airport's being required to hire 4 licensed engineers for 3 shifts and 1 relief. These are only a few of the many items in which care in design will result in reasonable operation costs.

Perhaps the greatest fault in the older terminals of this country was the lack of provision for expansion of the various major activities. Many of them were overcrowded when they opened for business. Very few had electrical and utility shafts capable of receiving the many new mechanical and electrical contrivances that have developed along with aviation. A terminal building will not remain adequate for any considerable length of time unless it is designed so that every major activity is free to expand without infringing upon the space of adjoining major activities. This may be accomplished by designing the building for both horizontal and vertical expansion and by

allowance for certain activities to enlarge by encroaching upon cargo space. Cargo space may be converted to other usages with very little lost investment.[13]

Airport Operation

Passenger Handling.—In order to see how some of these precepts have been incorporated into the design of Friendship International Airport, it is merely necessary to follow the route of a typical passenger leaving Baltimore by limousine or bus for the airport. The conveyance will turn off the Washington-Baltimore Expressway at Friendship Interchange and proceed into the airport via the mile-long access highway. The passenger will leave the vehicle at the lobby floor and proceed directly into the spacious main lobby. If by chance he had driven his own car, he would have parked it on the parking lot (capacity 1,400 cars) and entered directly into the lower lobby, thus avoiding the necessity of crossing the main flow of vehicular traffic. He then would take the moving stairs to the upper lobby. As he proceeds along the main lobby toward the ticket counters, which are immediately visible, he sees on either side of him a branch bank, a game room, a dining room, cocktail lounge, coffee shop, interesting display cases, and a merchandise mart in which many articles, attractive or useful to travelers, are for sale. In addition, just off the main lobby are located the men's and women's lounges, barber shop, cobbler shop, telephone room, and roomettes that may be rented by weary travelers. After checking in at the ticket counter, the passenger's baggage is conveyed by a spiral chute to the floor below, where it is picked up by airline employees and carried to the plane. The passenger waits in the main lobby and has an opportunity to patronize the concessions that he has seen as he came into the lobby. He may, if he has time to spare, proceed to the second floor and walk out upon the 500-ft long promenade deck that is open to the public upon payment of an admission fee of 10 cents. This promenade deck permits an intimate view of the entire airfield operation. Over 300,000 visitors used the deck during the first year of operation.

Upon hearing his plane departure announced, the passenger proceeds via 1 of the 3 piers to the loading position and as presently constructed (see following section on aircraft loading) goes down a flight of stairs to the apron level and proceeds across the apron to the plane. No fences or gates as such are provided. All passenger checking operations are conducted indoors. Friendship Airport has 8 fully equipped loading positions and 4 more that may be used during rush hours. Eventually, 40 or more positions may be provided. However, the passenger will never have to search for more than 1 out of 3 main doorways (Pier A, Pier B, or Pier C), all of which are visible from the main lobby.

Aircraft Loading.—In an effort to reduce the amount of small equipment that usually clutters up the apron of an airport, as many as possible of the utilities have been installed in the service pits. These pits contain a sewer connection, a storm water drain, a 1.5-in. cold water line, ducts for future communication lines, receptacles for 110-volt alternating current portable

[13] "World's Best Airport—Baltimore's Friendship Field," *Engineering News-Record*, Vol. 146, Feb. 1, 1951, p. 32.

lights, 26-volt direct current for starting plane engines, and conditioned air ducts to warm the planes in winter and cool them in summer. Insofar as it is deemed practicable, a passage through the airport has been made pleasant, simple, and efficient.

It is proposed to equip some or all of the plane loading positions with adjustable covered walkways reaching from the plane door to the lobby floor level of the pier, thus obviating the necessity for certain ramp equipment and for the passengers to walk across the apron (sometimes in bad weather) and to climb up a set of stairs into the plane. Window openings and landings are designed to fit such equipment when installed.

Arrival Procedure.—A passenger arriving at Friendship Airport on board a domestic plane will proceed through 1 of the same piers, in a reverse manner, and along the walkway into the main lobby. Here he may either wish to patronize some of the concessions or facilities available or he may wish to proceed by moving stairs immediately to the lower lobby to pick up his baggage. All busses, limousines, taxicabs, and private cars leave from this level.

A passenger arriving from overseas will disembark at the International Port, located at the extreme end of the central pier known as Pier B. Two plane loads of 60 passengers each, or 1 plane load of 120 passengers, may be accommodated at any one time. A comfortable waiting room with a snack bar and rest rooms is provided. The passenger from overseas passes, in order, first through the public health examination area, thence through the immigration examination rooms, and finally, through the customs area. After clearing through customs, he walks along Pier B directly into the main lobby where he has the same opportunity to patronize concessions and other facilities as does the domestic passenger and uses the same facilities for transportation and communication.

Service Areas

On the floor above the main lobby is located a serving kitchen, a roof garden, banquet and conference rooms, business offices used by local concerns, additional roomettes and, as previously mentioned, the public promenade or observation deck. The third floor is devoted to appropriate offices for the Baltimore City Department of Aviation, its director and his assistants, the airport manager, the CAA, and the United States Weather Bureau.

The tower extends from the fourth to the ninth floor and is devoted to CAA activities, such as a chief controller's office, radio and radar rooms, and the control cab. From the control cab all parts of the airfield and terminal are visible. A utilities shaft, sealed off at every floor for fire control purposes, extends from the service floor up to the under side of the control cab. Ample space has been provided for the installation of any future developments in electronics or other electrical navigation aids. A large freight and passenger elevator runs from the service floor to the third floor, and a smaller elevator runs from the third floor up through the tower to the seventh floor.

The service floor, at apron level, is occupied by airlines operations offices, baggage handling facilities, the lower lobby unloading docks, merchandise receiving and storage rooms, a large kitchen for the preparation of in-flight meals and another section devoted to the preliminary preparation of foods to be

finally prepared in the kitchens above. Refrigeration and air conditioning machinery are also found at this level, as well as truck unloading docks for air mail, air cargo, and air express, and adequate warehouse space. At the extreme end of Pier B is located an engine room for fire and crash equipment, plant quarantine rooms, and a bonded ware-room. At the present writing (1951) all rentable space is under lease.

Friendship Airport differs widely from any other airport now in existence. However, it has been designed and constructed as closely as practicable in accordance with the fundamental precepts outlined herein, and it is believed that it will be able to take care of the changing needs of aviation in Baltimore and its vicinity for many years to come.

Acknowledgment

Much of the credit for the successful completion of Friendship International Airport is due to businesslike administration by the Baltimore City Department of Aviation through two former directors, Major General Julian L. Schley, U.S.A., Retired, and Major General Cecil R. Moore, U.S.A., Retired, M. ASCE, and the present director, Major General Donald H. Connolly, U.S.A., Retired, M. ASCE. The master plan, design and supervision of construction for Friendship Airport were conceived and carried out by Whitman, Requardt-Greiner Company and Associates, Consulting Engineers. The author formerly was an associate of this company and project engineer for the airport.